A

Docket No. 14XZ00047

UTILITY PATENT APPLICATION TRANSMITTAL

TO: Box PATENT APPLICATION
Assistant Commissioner for Patents
Washington, DC 20231

Transmitted herewith for filing under 35 USC 111(a) and 37 CFR 1.53(b) and 35 USC 371 is a new

☒ utility ☐ design patent application for an invention entitled:

METHOD OF SEMIAUTOMATIC SEGMENTATION FOR THE ESTIMATION OF THREE-DIMENSIONAL VOLUMES

and invented by: Jérôme KNOPLIOCH and Eric STEFANI

If a continuation application:

☒ continuation ☐ division ☐ continuation-in-part
of prior application Serial No. PCT/FR98/02599

Enclosed are:

1. ☒ Specification having nine pages (9) comprising the following:
   - a. ☒ Claims numbered from 1 to 18
   - b. ☒ Abstract of the Disclosure
   - c. ☒ Drawing (s) as follows:
     - (1) ☒ Formal ☐ Informal
     - (2) Number of Sheets - three (3) with Figures No. 1 to 5
   - d. ☒ Oath or Declaration as follows:
     - (1) ☐ Original and signed
     - (2) ☒ Unsigned
     - (3) ☐ Copy from prior application Serial No. filed
     - (4) ☒ With Power of Attorney
     - (5) ☐ Without Power of Attorney
2. ☐ Incorporation by Reference (if Box 1d(3) is checked)
3. ☐ Assignment
   - ☐ Recordation Cover Sheet
   - ☐ Document

4. ☒ Preliminary Amendment

5. ☒ Acknowledgment Postcard

6. ☒ Certificate of Mailing by "Express Mail"

I hereby certify that this paper or fee is being deposited with the United States Postal Service "Express Mail Post Office to Addressee" service under 37 CFR 1.10 as Express Mail No. EJ870850292US on August , 1999 and is addressed to the Assistant Commissioner for Patents, Box PATENT APPLICATION, Washington, DC 20231.

Dolores K Tillson

(Name and Date) Dolores K. Tillson, August 4, 1999

7. ☒ Filing fee calculated and transmitted:

a. ☒ as described below for the claims as filed

			Small Entity		Large Entity	
For	No. Filed	No. Extra	Rate	Fee	Rate	Fee
Basic				$ 380		$ 760
Total Claims	18 - 20 =	-0-	x$ 9 =	$	x$ 18 =	$
Ind. Claims	1 - 3 =	-0-	x$ 39 =	$	x$ 78 =	$
Mult. Dep. ☐			+$130 =	$	+ $260 =	$
Total Filing Fee				$		$ 760

b. ☐ see attached PTO-1398 for Transmittal Letter to US Designated/Elected Office for National Stage of PCT

c. ☐ design filing fee

d. ☒ The Commissioner is hereby authorized to charge and credit Deposit Account No. 09-0470 as described below. A duplicate copy of this sheet is enclosed.

(1) ☒ Charge the amount of ☐ $310.00 ☒ $760.00 as filing fee.

(2) ☒ Credit any overpayment.

(3) ☒ Charge any additional filing fees required under 37 CFR 1.16 and 1.17.

(4) ☐ Charge the Issue Fee set in 37 CFR 1.18 at the mailing of the Notice of Allowance, pursuant to 37 CFR 1.311(b).

d. ☐ A check in the amount of $ to cover the filing fee is enclosed.

8. ☒ Information Disclosure Statement

a ☒ PTO-1449

b. ☒ Copies of Cited Documents

9. ☐ Certified Copy of Priority Document

Country
Filing Date
Application No.
Applicant

10. ☐ Verified Statement to establish Small Entity status under 37 CFR 1.9 and 37 CFR 1.27

11. ☒ Additional Enclosures as follows:

a. ☒ Translation of the International Application (corresponding to the FR priority application which was not amended in the International Phase)

b. ☒ Copy of International Application published as WO99/30281 on 17 June 1999

Date: August 4, 1999

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PATENT
14XZ00047

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Application of KNOPLIOCH ET AL	: METHOD OF SEMIAUTOMATIC SEGMENTATION FOR THE ESTIMATION OF THREE-DIMENSIONAL VOLUMES
Serial No.:	: Group Art Unit:
Filing Date: 02 December 1998	
International Application No. PCT/FR98/02599	: International Filing Date: December 2, 1998

August 4, 1999
Fairfield, CT

PRELIMINARY AMENDMENT

Attn: BOX PATENT APPLICATION
Assistant Commissioner for Patents
Washington, DC 20231
Sir:

Please amend the specification as follows:

Page 1, before the first line of the text insert: -- This is a continuation application of International Application No. PCT/FR98/02599 filed December 2, 1998. --

REMARKS

The Utility Application Transmittal Letter accompanying the entry into the US national stage request that the filing be considered in accordance with 35 USC 111(a) and 37 CFR 1.53(b) and 35 USC 371. The application is amended to recite the continuation status of the application and thereby the date accorded to the application for 35 USC 102(e) is the International Filing Date.

A certified copy of the priority French application No. 97 15639 filed December 10, 1997 is enclosed or will be submitted promptly.

Respectfully submitted,

Jay L. Chaskin
Attorney for Applicant

METHOD OF SEMIAUTOMATIC SEGMENTATION FOR THE ESTIMATION OF THREE-DIMENSIONAL VOLUMES

BACKGROUND OF THE INVENTION

The present invention concerns the estimation of the volume of a three-dimensional object, notably, in medical imagery.

In some medical imagery applications, there is a need to know precisely the volume of three-dimensional objects like, for example, an organ or an organ part of the human body.

It is possible through such methods to approximate the volume of an object by knowing the contour of that object along different sections, the outline between the sections then being modeled by a continuous slope. The three-dimensional object is thus modeled by a plurality of thin truncated cone-shaped volumes. However, this method requires an operator to plot the contour of the object, which demands slow and painstaking work.

BRIEF SUMMARY OF THE INVENTION

The present invention seeks to solve the problems of the above procedure by proposing a method that is simple, easy to use and enables the desired precision to be obtained in a short time.

The method is intended for estimation of the volume of a three-dimensional object in medical imagery, a contour of the object being known by means of a plurality of films taken in section.

The method comprises the following steps:

- define a given number of base points constituting a first three-dimensional shape defined by facets whose vertices are the base points;

- each facet of the first shape being defined by three segments and each segment being common to two adjacent facets, the segments are divided by creating second rank points adapted to the contour of the object, so as to constitute a second three-dimensional shape closer to the contour of the object than the first shape, the creation of a second rank point resulting in the creation of two new facets and three new segments;

- each segment is iteratively divided into subsegments adjusted by defining third rank points adapted to the contour of the object, so as to constitute a third three-dimensional shape closer to the contour of the object than the second shape, the creation of a third rank point resulting in the creation of two new facets and three new segments; and

- then, the volume of the third three-dimensional shape is calculated.

Thus, only points have to be defined and not a contour, which facilitates the work.

In one embodiment of the invention, the films are taken along parallel sections.

In another embodiment of the invention, a plurality of films is treated to supply a description of the three-dimensional volume.

Each segment is advantageously divided into two.

In one embodiment of the invention, the position of each second point is proposed as a function of the position of the first two adjacent points. Each second point can thus be proposed as a function of the orientation of the perpendiculars to the first two adjacent points.

In one embodiment of the invention, the segments are divided into subsegments until the change of volume resulting from a given division is

negligible. One can thus choose a change of threshold volume below which the iterative division into subsegments is stopped. Said threshold of change of volume corresponds to the desired precision of the method.

In one embodiment of the invention, six first base points, available on top and bottom, in front and back and on each side edge of the object, are defined.

A calculation of distribution of the density of the object in space can be made subsequent to calculation of the estimated volume of the object.

Any point of the three-dimensional shapes can be modified manually, for example, to adapt it to an irregularity in the relief of the object, such as a hollow or a boss. A different weighting is given to the points in order to approximate the real contour of the object as closely as possible. A modification of a first base point will result in a corresponding modification of the set of neighboring points. On the other hand, a modification of a third point of the third shape will not result in any modification of the first and second adjacent points and may slightly modify the position of the third adjacent points. Improvements of the different shapes leading to bringing them closer to the real contour of the three-dimensional object can thus be carried out very flexibly.

Similarly, to preserve a great flexibility of use, any point, including third rank, can be defined manually.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will be better understood and other advantages will emerge from the detailed description of an embodiment taken nonlimitatively and illustrated by the attached drawings, wherein:

Figure 1 is a view in perspective of a final shape according to an embodiment of the invention;

Figures 2 and 3 are two-dimensional schematic views of the method according to the invention; and

Figures 4 and 5 are three-dimensional schematic views of the method according to an embodiment of the invention.

DETAILED DESCRIPTION OF THE INVENTION

As can be seen in Figure 4, a final shape approximating a three-dimensional object is formed by a plurality of facets defined by three segments, for example, segments 1 to 3, defining a flat triangular surface 4. The volume of the three-dimensional object, not represented, is thus approximated by means of triangular surfaces, the coordinates of whose vertex points are known. The volume of the shape can thus be calculated.

An operator begins by defining six points of the object, an upper point 11, a lower point 12, a left side point 13, a right side point 14, a front point 15 and a back point not visible in Figure 1. This first shape thus roughly defines the three-dimensional object, and these six points must be positioned precisely, for on their definition depends that of the future adjacent points. In order to obtain a satisfactory definition, it may be necessary to check their positioning on different sections of the object.

After having defined the six first points, an oblique view is added to the existing view, making it possible by orientation and centering to define additional points.

The additional points can then be defined at the intersection of the perpendicular to one of the segments of the base volume, the perpendicular being calculated from the facets and points forming that segment, and from the edge of the three-dimensional object studied. A number of second points constituting a second shape is defined manually or automatically. When the

change of volume resulting from the definition of second points becomes less than a threshold, the definition of points can then be continued automatically, proceeding with the segmentation of existing facets until a sufficient correspondence with the three-dimensional object studied is obtained, thus constituting a third shape. The definition of points can, nevertheless, be pursued manually.

When the final volume is defined, points whose definition does not satisfactorily correspond to an irregularity in the three-dimensional object studied, notably, a hollow or a protuberance, can be modified. The point is then displaced according to the perpendicular to the facet to which the point belongs, the perpendicular being calculated from the facets.

The points adjacent to the points modified will also be modified in order to maintain the regularity of the volume defined, by taking into account the belonging of said point to the first, second or third shape. The displacement of a point of the first shape results in a corresponding displacement of all the adjacent points. The displacement of a point of the third shape does not result in displacement of adjacent points of the first and second shapes.

Figures 2 and 3 show schematically, in two dimensions, the process of definition of the points. From a contour 20, first base points 21 to 23 are defined and make it possible roughly to define said contour 20. The straight-line segments 24 to 26 joining the first base points 21 to 23 are then defined. The perpendiculars 27 to 29 to those segments 24 to 26 are then calculated. Second points 30 to 32 more precisely approximating the contour 20 can then be defined by being displaced along perpendiculars 27 to 29. The segments 33 to 38 joining points 21 to 23 and 30 to 32 are then defined, which makes it possible to reproduce the previous stages manually, semiautomatically or automatically until the desired precision is obtained.

Figures 4 and 5 show schematically, in three dimensions, the process of definition of the points. Two facets 40 and 41 belonging to a contour are represented. Facet 40 is limited by base points 42, 43 and 44. Facet 41 is limited by base points 43, 44 and 45. Base points 43 and 44 are therefore common to facets 40 and 41 and define a segment 46. A second-order point 47 is next defined, which results in the creation of additional facets 48 and 49 and additional segments 50 to 52.

In the invention, a method of estimation of the volume of a three-dimensional object suited to X-ray imagery is made available, which is easy to use, for there is only a small number of points to be defined on the edge of the three-dimensional object, as is easy to check, which guarantees a good approximation of the contour in rapid time, since the automatic definition phase can be carried out in a few seconds and is readily reproducible, insofar as it is based on the definition of a small number of points on the contour of the object.

Various modifications in structure and/or steps and/or function may be made by one skilled in the art to the disclosed embodiments without departing from the scope and extent of the invention.

WHAT IS CLAIMED IS:

1. A method of estimation and segmentation of the volume of a three-dimensional object, a contour of the object being known by means of a plurality of films taken in section, comprising the steps:

(a) define a given number of base points constituting a first three-dimensional shape defined by facets whose vertices are the base points;

(b) each facet of the first shape being defined by three segments and each segment being common to two adjacent facets, the segments are divided by creating second rank points adapted to the contour of the object, so as to constitute a second three-dimensional shape closer to the contour of the object than the first shape, the creation of a second rank point resulting in the creation of two new facets and three new segments;

(c) each segment is iteratively divided into subsegments adjusted by defining third rank points adapted to the contour of the object, so as to constitute a third three-dimensional shape closer to the contour of the object than the second shape, the creation of a third rank point resulting in the creation of two new facets and three new segments; and

(d) then, the volume of the third three-dimensional shape is calculated.

2. The method according to claim 1, wherein the films are taken along parallel sections.

3. The method according to claim 1, wherein a plurality of films is treated to supply a description of the three-dimensional volume.

4. The method according to claim 1, wherein each segment is divided in two.

5. The method according to claim 2, wherein each segment is divided in two.

6. The method according to claim 3, wherein each segment is divided in two.

7. The method according to claim 1, wherein the position of each second point is proposed to the operator as a function of the position of the first two adjacent points.

8. The method according to claim 2, wherein the position of each second point is proposed to the operator as a function of the position of the first two adjacent points.

9. The method according to claim 3, wherein the position of each second point is proposed to the operator as a function of the position of the first two adjacent points.

10. The method according to claim 4, wherein the position of each second point is proposed to the operator as a function of the position of the first two adjacent points.

11. The method according to claim 5, wherein the position of each second point is proposed to the operator as a function of the position of the first two adjacent points.

12. The method according to claim 6, wherein the position of each second point is proposed to the operator as a function of the position of the first two adjacent points.

13. The method according to claim 7, wherein the position of each second point is proposed as a function of the orientation of the perpendiculars to the first two adjacent points.

14. The method according to claim 1, wherein the segments are divided into subsegments until the change of volume resulting from a given division is negligible.

15. The method according to claim 1, wherein six first base points are defined.

16. The method according to claim 1, wherein the distribution of density of the object in space is calculated.

17. The method according to claim 1, wherein any point of the three-dimensional shapes can be modified.

18. The method according to claim 1, wherein the points are defined manually.

METHOD OF SEMIAUTOMATIC SEGMENTATION FOR THE ESTIMATION OF THREE-DIMENSIONAL VOLUMES

ABSTRACT OF THE DISCLOSURE

Method of estimation and segmentation of the volume of a three-dimensional object in medical imagery, in which:

- one defines a given number of base points constituting a first three-dimensional shape defined by facets;

- each facet of the first shape being defined by three segments, the segments are divided by defining second order points adapted to the contour of the object, so as to constitute a second three-dimensional shape closer to the contour of the object than the first shape;

- each segment is iteratively divided into subsegments adjusted by defining third order points adapted to the contour of the object, so as to constitute a third three-dimensional shape closer to the contour of the object than the second shape;

- then, the volume of the third three-dimensional shape is calculated.

FIG.1

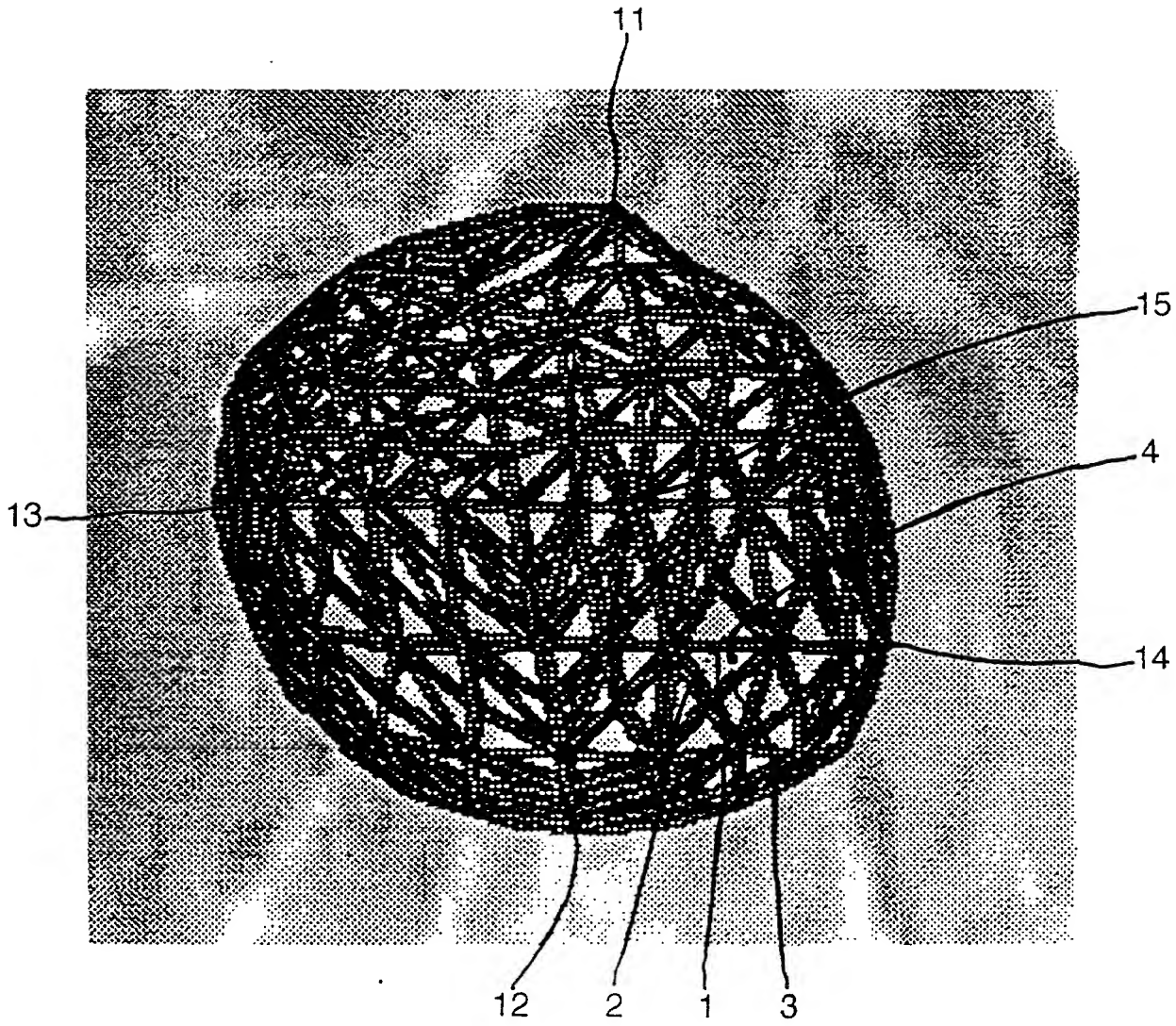

FIG.2

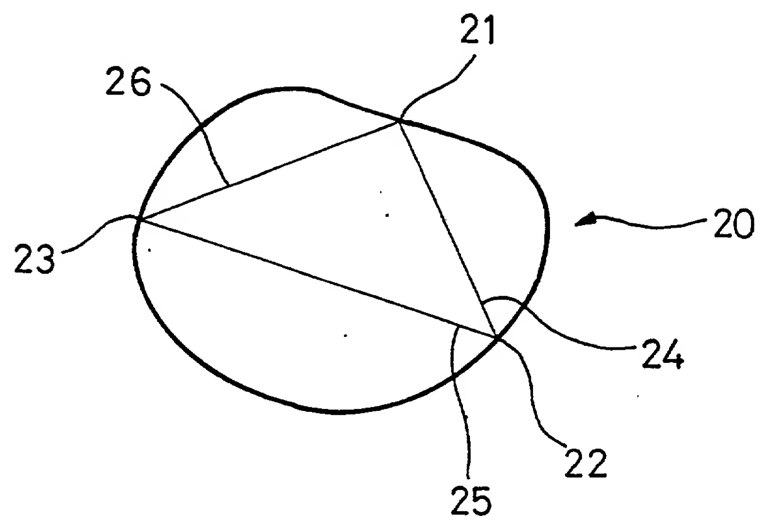
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FIG.3

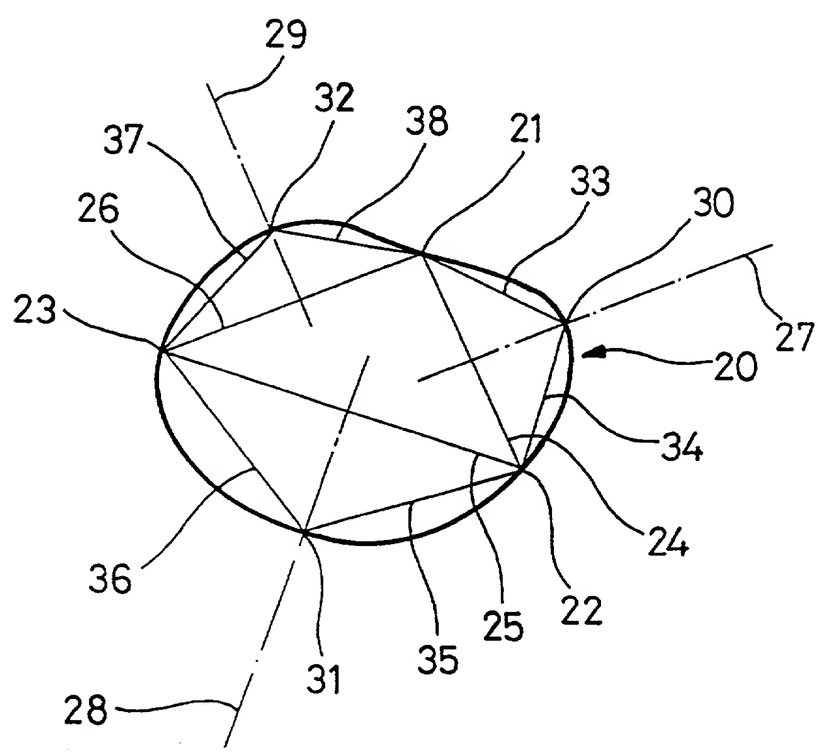
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FIG.4

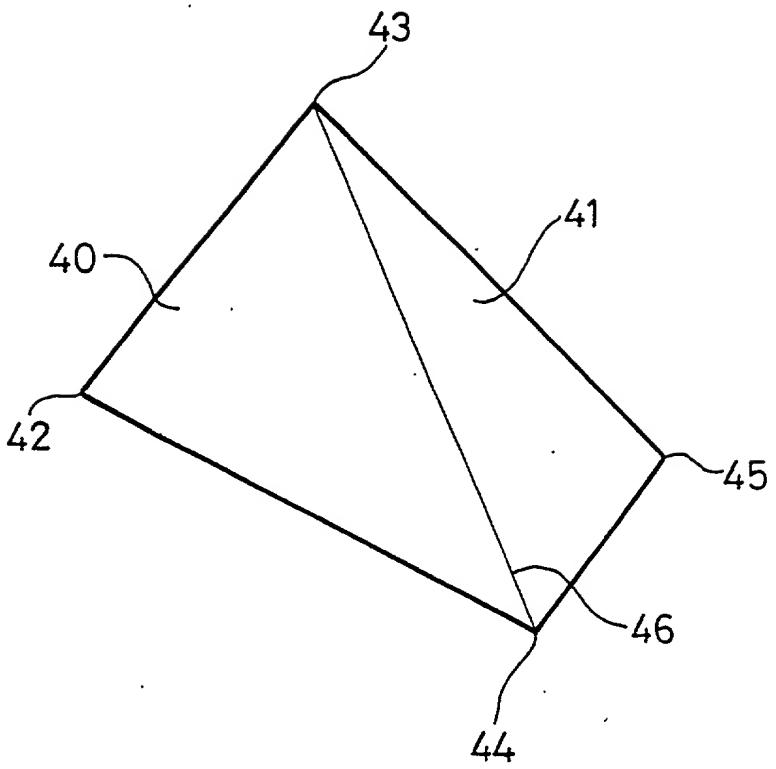
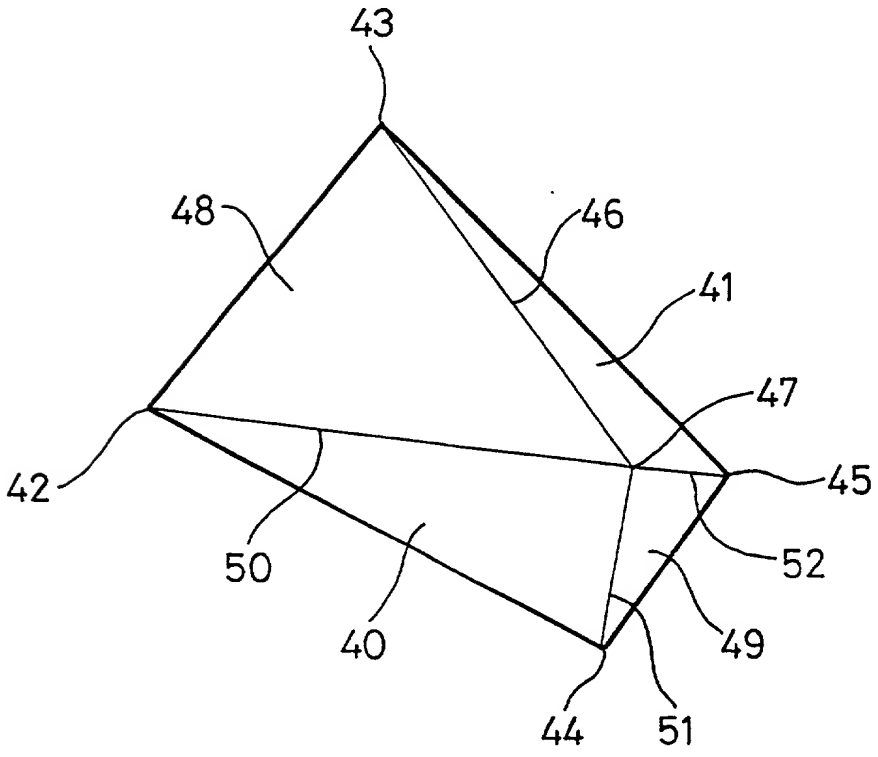


FIG.5



PATENT
Docket No. 14XZ00047

COMBINED DECLARATION AND POWER OF ATTORNEY FOR PATENT APPLICATION

As a below-named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name.

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled:

METHOD OF SEMIAUTOMATIC SEGMENTATION FOR THE ESTIMATION OF THREE-DIMENSIONAL VOLUMES

☐ the specification of which is attached hereto OR

☒ was filed on December 2, 1998 as Application Serial No. or PCT International Application Number PCT/FR98/02599 and was amended on (if applicable).

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose information which is material to the examination of this application in accordance with 37 CFR §1.56.

I hereby claim foreign priority benefits under 35 U.S.C.§119(a)-(d) or 365(b) of any foreign application for patent or inventor's certificate listed below, and have also identified below any foreign application for patent or inventor's certificate having a filing date before that of the application on which priority is claimed:

COUNTRY	APPLICATION NUMBER	DATE OF FILING (day, month, year)	PRIORITY CLAIMED UNDER 37 U.S.C. 119
France	97 15639	10 December 1997	☒ Yes ☐ No
			☐ Yes ☐ No

I hereby claim the benefit under 35 U.S.C. §120 of any United States application(s), or 365(c) of any PCT International application designating the United States of America, listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of 35 U.S.C. §112, I acknowledge the duty to disclose material information as defined in 37 CFR §1.56 which occurred between the filing date of the prior application and the national or PCT international filing date of this application:

U.S. PARENT APPLICATION OR PCT PARENT NUMBER	PARENT FILING DATE (day, month, year)	STATUS (patent and number, pending, abandoned)
PCT/FR98/02599	02 December 1998	

I hereby claim the benefit under 35 U.S.C. 119(e) of any United States provisional application(s)listed below.

APPLICATION NUMBERS (S)	FILING DATE (day, month, year)

As a named inventor, I hereby appoint Christian G. Cabou (Reg. No. 35,467) and Phyllis Y. Price (Reg. No. 34,234) both of GE Medical Systems, 3000 North Grandview Blvd., Waukesha, Wisconsin 53188; Ronald E. Myrick (Reg. No. 26,315), Henry J. Policinski, (Reg. No. 26,621), and Jay L. Chaskin, (Reg. No. 24,030) all of General Electric Company, 3135 Easton Turnpike, Fairfield, Connecticut 06431-0001 jointly, and each of them severally, my attorneys, with full power of substitution, delegation and revocation, to prosecute this application, to make alterations and amendments therein, to receive the patent and to transact all business in the Patent and Trademark Office connected therewith.

I hereby direct that all correspondence and telephone calls in connection with this application be addressed to Jay L. Chaskin, General Electric Company, 3135 Easton Turnpike, Fairfield, Connecticut 06431-0001; telephone number: 203-373-2867, fax number: 203-373-3991.

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that all such willful false statements may jeopardize the validity of the application or any patent issued thereon.

Full name of first sole or joint inventor: Jérôme KNOPLIOCH

Inventor's signature: _____ Date:_____

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Full name of second joint inventor: Eric STEFANI

Inventor's signature: _____ Date: _____

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Post Office Address: same as residence